Enhancing groundnut productivity and production in Bangladesh and India

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Summary

Bangladesh: In phase II, a total of 131 PVS trials were conducted in nine districts. Two short duration high yielding varieties, BARI Chinabadam-8 and BINA Chinabadam 4, were identified to replace an obsolete groundnut variety, Dhaka 1. New crosses involving nine parental lines were made, and promising selections were made from the evaluated breeding populations (F_2 to F_5). Previously, 72 lines were received from ICRISAT – India and were evaluated. The superior lines were selected for early maturity, large seed size and high yield as edible types.

India: The TL II project was conducted in two phases and this report highlights the progress through 2008 to 2013. In phase I, Karnataka and Tamil Nadu were included while in phase II, Bihar and Odisha were added along with the phase I states. Through PVS and paired comparison (PC) trials conducted over years, a number of promising varieties were identified. The farmers' preferred varieties in Bihar were ICGV 02266 and ICGV 91114 in Araria and Purnea districts and ICGV 93648, ICGV 89280 and ICGV 91114 in Jehanabad and Nawada districts. The Farmers' in Araria also preferred Dh 86 for spring season cultivation. ICGV 91114, GPBD 4, ICGV 00350, Chintamani-2 and R2001-2 in Karnataka and ICGV 02266 in Odisha have been identified as the most promising varieties by the farmers. In Tamil Nadu, a Virginia bunch variety, ICGV 87846 (CO 6) and a Spanish bunch variety, ICGV 00351 (CO 7) have been released for cultivation. Other varieties selected through multilocation evaluations were CTMG 6, CTMG 7 and Dh 236 in Karnataka; ICGV# 02266, 07220, 04623, 07213 and 10004 in Odisha; ICGV# 01263, 96155, 02266, 03128, 06146, 07018 and COG 0402 in Tamil Nadu, which will be entered in states or national trials for further evaluation. UAS Dharwad and UAS Bangalore identified 10 and 24 varieties, respectively from the international trials. Tamil Nadu Agricultural University (TNAU) identified seven varieties either with resistance to drought or high oil types. To support breeding programs, ICRISAT made over 900 crosses and provided project partners 192 sets of international trials, 449 advanced lines and 236 trait-specific breeding populations. The participating centers also generated their own breeding populations involving ICRISAT-bred varieties and made large number of single plant selections and bulks for further evaluations.

Seven scientists from Bangladesh were trained on various aspects of groundnut breeding, including integrated molecular breeding. In India, a manually operated rainout shelter for phenotyping drought tolerance, equipment for measuring drought tolerance, and sprinkler irrigation systems for screening for resistance to foliar diseases were established at some of the centers in Karnataka and Tamil Nadu. Six students (three each for PhD and MSc) have successfully completed their research and submitted their thesis under this project. A total of 10 scientists or technicians received hands-on training on groundnut breeding, screening for resistance to virus diseases, data management and statistical modules and on integrated molecular breeding.

Background

Bangladesh: Groundnut is the third important oilseed crop in Bangladesh and is mainly consumed as roasted nut (*badam*) or as confectionary item. The acreage and production in 2011 was 87,576 ha and 139,333 t, respectively, accounting for 11% and 17% of total oilseed cropped area and production in Bangladesh, respectively (DAE, 2012). Groundnut is the principal crop of Char land and is cultivated in the Char areas that generally remains submerged in water throughout the rainy season (June to September). The soils in Char agro-ecologies are highly prone to soil erosion and are characterized by sand to sandy-loam type, low soil-water holding capacity and poor nutritional status of soils. Most of the areas consist of riverbed and riverine region. In every 3 – 5 years, the Char area is increased by 36,000 ha, which should be considered for crop production. Groundnut is cultivated in post-rainy season. The major groundnut growing districts are Dhaka, Mymensingh (Dhaka division), Comilla, Chittagong, Rangamati (Chittagong division), Sylhet (Sylhet division), Jessore, Rajshahi (Khulna division) and Rangpur (Rangpur division). The key constraints to groundnut production include lack of quality seed production and supply, cultivation of obsolete variety (Dhaka 1), drought, poor soil fertility coupled with low input use, lack of awareness on production technology and trained manpower and lack of storage facilities. Dhaka-1, an age-old variety, is preferred by farmers for its early maturity. Bangladesh participated in TL II phase II project (2011 to 2013) to strengthen its groundnut breeding program and identify promising varieties for cultivation.

India: Globally, India holds the second position in terms of total groundnut production. Groundnut oil accounts for the third largest oil produced in India after rapeseed and soybean oil (FAO Stat, 2012). The groundnut acreage in India declined by 30.1% from 8.3 m ha in 1991– 1993 to 5.8 m ha in 2009 – 2011. However, the average productivity increased by 28.5% from 924 to 1188 kg ha^{-1} during the same period, which led to 10.4% decline in total production from 7.7 to 6.9 million tons. The groundnut cropped area during the rainy season declined by 29% while the post-rainy season cropped areas reduced by 38.5% during the same period. The linear productivity growth was higher (18 kg per year) in post-rainy season than the rainy season (14.5 kg per year). The decadal-wise linear growth in nation's productivity was in increasing trend (7 kg/year in 1970 – 1980 to 26 kg/year in 2000 – 2010) over the last four decades period. Several reasons contribute to low productivity, which includes abiotic and biotic stresses, lack of access to quality seeds and other inputs and improved technologies. However, there exists an enormous potential to improve the groundnut yields in the country through adoption of improved varietal technology by the farmers and quality seed supply.

In Bihar, groundnut is mainly grown in Araria, Purnea, Nawada and Jehanabad districts. Two crops, namely *kharif* and spring or summer, are commonly grown. The spring or summer groundnut is fully irrigated while *kharif* crop is rain-fed. The production in *kharif* is hampered by heavy rainfall. Some districts (Nawada, Jehanabad, Gaya and Rohtas) receive less rainfall therefore, providing a good scope to cultivate groundnut as seed crop with yields of about 1 ton ha^{-1}. Short duration varieties with resistance to foliar diseases and some level of tolerance to drought with seed dormancy are needed. R 20 is the most commonly grown and preferred cultivar. In Karnataka, the major groundnut producing districts (with more than 40,000 ha) are Chitradurga, Tumkur, Bellary, Gadag, Koppal and Bijapur. The groundnut yields are low as the crops suffer from moisture stress and susceptibility to insect pests and diseases. Groundnut is also grown as post-rainy season irrigated crop (with more than 20,000 ha) in Bagalkot, Bijapur, Yadgir and Raichur districts. TMV 2 is a widely grown cultivar. Other varieties introduced and popularized in the state are GPBD4 and ICGV 91114. The groundnut production in Odisha is about 79,000 t, with major produce (68.5%) from post-rainy season crop after paddy with an average productivity of 1,189 kg ha^{-1}. TMV 2, AK 12- 24, Smruti and Kishan are the most popular varieties. In Tamil Nadu, groundnut is grown in about 0.38 m ha with a production of 1.06 t. The state recorded highest productivity (2,751 kg ha^{-1}). About 62% of the crop acreage is under rainfed conditions. The most commonly grown varieties include TMV 7, VRI 2, VRI 3, Co Gn 4 and TMV Gn 13.

The Bill & Melinda Gates Foundation supported TL II project ran for six years in two phases in the selected states in India and three years in Bangladesh. In phase I, the states of Karnataka and Tamil Nadu were included while in phase II, Bihar, Karnataka, Odisha and Tamil Nadu were included from India. Bangladesh was included in phase II. This report details the progress achieved towards developing or identifying improved groundnut varieties and capacity building (both human capital and infrastructure development) to support the development of improved varieties.

Key achievements

A. Crop improvement

PVS

Bangladesh

PVS were conducted in Jamalpur, Mymensingh, Kishoregong, Lalmonirhat, Kurigram, Pabna, Panchagarh, Noakhali and Cox's Bazzar districts. Four early maturing groundnut varieties were evaluated in 131 trials, and two varieties (BARI Chinnabadam 8 and BINA Chinnabadam 4) were identified, which produced 28 – 58% greater pod yield over local control that were found suitable for cultivation.

India (Bihar)

PVS trials involving eight Spanish bunch varieties were conducted in four villages each in Araria, Purnea, Jehanabad and Nawada districts. A total of 80 PVS trials in 2012 and 40 paired comparisons (PC) trials in 2013 were conducted. In Araria and Purnea, ICGV 02266 emerged as a preferred variety and recorded a 25% pod yield increase over the local check. ICGV 93648 and ICGV 91114 were farmer-preferred varieties in Jehanabad and Nawada districts. Dh 86 is also preferred by farmers of Araria district for spring cultivation.

Karnataka

UAS, Bangalore: A total of 625 PC trials of the improved varieties (ICGV 91114 and Chintamani 2) with local variety (TMV 2) were conducted in the farmers' fields in four districts. ICGV 91114 on an average across 429 demonstrations produced 25% greater yield over TMV 2 (average pod yield, 1,323 kg ha^{-1}) (Table 9) while Chintamani 2 showed 29% greater pod yield over TMV 2 (average pod yield, 1,379 kg ha^{-1}) (Table 10).

Table 9. Performance of ICGV 91114 and TMV 2 in PVS and PC trials in four districts of Karnataka, 2008 to 2013, rainy seasons.

			Pod yield (kg ha^{-1})		
Season	Name of the trial	No. of demonstration	ICGV 91114	TMV 2	Superiority over TMV 2 (%)
2008 rainy	PVS	9	1,073	1,076	–
2009 rainy	PVS	12	1,490	1,180	26
2010 rainy	PC	33	823	640	28
2011 rainy	PC	150	1,825	1,423	28
2012 rainy	PC	100	1,734	1,521	14
2013 rainy	PC	125	1,645	1,257	31
Total / Mean		429	1,649	1,323	25

PVS = participatory variety selection; PC = paired comparisons

Table 10. Performance of Chintamani-2 (KCG-2) in PVS and PC trials in three districts of Karnataka during rainy season.

Season	Name of the trial	No. of demonstration	Pod yield (kg ha^{-1})		
			Chintamani 2	TMV 2	Superiority over TMV 2 (%)
2008 rainy	PVS	9	1,527	1,076	42
2009 rainy	PVS	13	1,593	1,180	35
2011 rainy	PC	50	1,921	1,381	39
2012 rainy	PC	75	1,875	1,652	14
2013 rainy	PC	125	1,698	1,257	35
Total / Mean		272	1,777	1,379	29

PVS = participatory variety selection; PC = paired comparisons

UAS, Bangalore: A total of 100 frontline demonstrations (0.4 ha each), involving ICGV 91114, Chintamani 2 and TMV 2, were conducted at farmers' fields in Chitradurga, Tumkur, Chikballapur and Kolar districts. ICGV 91114 and Chintamani 2 on an average produced greater pod yield of 23% and 19%, respectively, over TMV 2 (Tables 11 and 12).

Table 11. Performance of ICGV 91114 in frontline demonstrations in four districts of Karnataka.

Season	Name of the trial	No. of demonstration	Pod yield (kg ha^{-1})		
			ICGV 91114	TMV 2	Superiority over TMV 2 (%)
2011 rainy	FLD	20	1,700	1,425	19
2012 rainy	FLD	20	1,773	1,458	22
2013 rainy	FLD	10	1,896	1,432	32
Total / Mean		50	1,768	1,440	23

FLD = Frontline demonstrations

Table 12. Performance of Chintamani 2 in frontline demonstrations in four districts of Karnataka.

Season	Name of the trial	No. of demonstration	Mean pod yield (kg ha^{-1})		
			Chintamani 2	TMV 2	Superiority over TMV 2 (%)
2011 rainy	FLD	20	1,757	1,472	19
2012 rainy	FLD	20	1,709	1,468	16
2013 rainy	FLD	10	1,800	1,475	22
Total / Mean		50	1,746	1,471	19

FLD = frontline demonstrations

UAS, Dharwad: The FPV trial in 2011 rainy season was conducted on 96 farmers' fields in Badami, Bagalkot and Bilagi in Bagalkot district. ICGV 00350 produced an average of 13% greater pod yield over TMV 2 (pod yield, 1,145 kg ha^{-1}) (Table 13). In 2012 rainy season, the PC trial was conducted on 20 farmers' fields in Bagalkot district. ICGV 00350 on an average produced 19% greater pod yield over

Table 13. Average performance of ICGV 00350 and TMV 2 in farmers' fields in Bagalkot district, Karnataka during the rainy season, 2011.

Panchayat	No. of farmer	Pod yield (kg ha^{-1})		
		ICGV 00350	TMV 2	Superiority over TMV 2 (%)
Badami	43	1,302	1,150	13
Bagalkot	28	1,261	1,125	12
Bilagi	25	1,307	1,158	13
Total / Mean	96	1,291	1,145	13

TMV 2 (pod yield, 1,902 kg ha^{-1}). In 2013 rainy season, PC trial was conducted on seven farmers' fields in Bagalkot district. ICGV 00350 on average produced 10% greater pod yield over TMV 2 (pod yield, 1987 kg ha^{-1}).

ICGV 00350 in 2009 and 2010 rainy seasons produced 43 – 78% greater pod yield over TMV 2 (Table 14) in large scale (0.4 ha) field trials in Bagalkot while in 2008 rainy season, it produced 226% greater pod yield over TMV 2 due to heavy incidence of foliar diseases. ICGV 00350 was most preferred by the traders.

Table 14. Performance of ICGV 00350 in PVS trials conducted at Badami, Bagalkot and Bilagi, in Bagalkot district, during the rainy seasons of 2009 and 2010.

2009 rainy

Variety	Mean pod yield (kg ha^{-1})			Average pod yield (kg ha^{-1}) (7 villages and 20 farmers)	Superiority over TMV 2 (%)
	Badami (2 villages and 10 farmers)	Bagalkot (2 villages and 6 farmers)	Bilagi (3 villages and 4 farmers)		
ICGV 00350	1,655	2,700	2,670	2,172	78
TMV 2	899	1,643	1,380	1,218	

2010 rainy

Variety	Mean pod yield (kg ha^{-1})			Average pod yield (kg ha^{-1}) (192 trials)	Superiority over TMV 2 (%)
	Badami (76 trials)	Bagalkot (102 trials)	Bilagi (14 trials)		
ICGV 00350	1,482	1,482	1,478	1,482	43
TMV 2	1,028	1,039	1,057	1,036	

UAS, Raichur: On an average, ICGV 00350 and R2001-2 produced 114% to 116% greater pod yield over TMV 2 (Table 15). However, both the varieties have some drawbacks from farmers' perspectives: no fresh seed dormancy in ICGV 00350 and low shelling turnover (%) in R2001-2. ICGV 00350 was also evaluated in PVS trials during 2010 rainy season in Raichur district. On an average, ICGV 00350 produced 44% greater pod yield over TMV 2 (pod yield of 937 kg ha^{-1}) (Table 16).

Table 15. Performance of selected varieties in paired comparison trials, 2012 rainy season, Raichur district, Karnataka.

Varieties	Pod yield (kg ha^{-1})				% increase over TMV 2
	Taluk			Mean	
	Raichur	Deodurga	Lingasugur		
ICGV 00350	976	1,147	945	1,023	114
TMV 2 (C)	467	543	425	478	
R 2001-2	1,015	1,236	915	1,055	116
TMV 2 (C)	512	488	466	489	

Yield levels are low in Raichur and Lingasugur due to low rainfall

Table 16. Performance of ICGV 00350 and local check, 2010 rainy season, Raichur district, Karnataka.

Varieties	Pod yield (kg ha^{-1})				% increase over TMV 2
	Taluk			Mean	
	Raichur	Deodurga	Lingasugur		
ICGV 00350	1,456	1,163	1,425	1,348	44
Local check	959	890	964	937	

Odisha

OUAT, Bhubaneswar evaluated three varieties (ICGV# 00308, 02266 and 07213) together with control (Smruti) in PVS trials in target districts, and farmers identified ICGV 02266 as the best performing variety.

Tamil Nadu

A Virginia bunch variety, ICGV 87846, which was evaluated in PVS and PC trials in 985 trials during 2008 – 2013 rainy seasons in Namakkal district, produced an average of 41% greater pod yield over local control (1,066 kg ha^{-1}) (Table 17). A Spanish bunch variety, ICGV 00351, was evaluated in 731 PVS and PC trials in Erode district during 2008 – 2013 rainy seasons and in 720 PVS and PC trials in Thiruvannamalai during 2009 – 2013 rainy seasons. In Erode district, ICGV 00351 produced 30% greater pod yield over TMV Gn 13 (pod yield, 1,340 kg ha^{-1}) (Table 18) while in Thiruvannamalai district, it produced 20% greater pod yield over TMV Gn 13 (pod yield, 1,587 kg ha^{-1}) (Table 19). Both the varieties have been released as CO 6 (ICGV 87846) and CO 7 (ICGV 00351) for cultivation in these districts in Tamil Nadu.

Table 17. Performance of ICGV 87846 in on-farm trials in Namakkal district of Tamil Nadu, from 2008 to 2013 rainy seasons.

Season	Name of the trial	No. of trials	Mean pod yield (kg ha^{-1})		Superiority over local (%)
			ICGV 87846	Local	
2008 rainy	PVS	90	1,630	869	88
2009 rainy	PC	237	1,019	646	58
2010 rainy	PC	198	1,985	1,457	36
2011 rainy	PC	150	1,984	1,634	21
2012 rainy	PC	160	1,340	888	51
2013 rainy	PC	150	1,245	954	31
Total / Mean		985	1,503	1,066	41

PVS = participatory variety selection; PC = paired comparisons

Table 18. Performance of ICGV 00351 in on-farm trials in Erode district, Tamil Nadu, from 2009 to 2013 rainy seasons.

Season	Name of the trial	No. of trial	Mean pod yield (kg ha^{-1})		Superiority over TMV Gn 13 (%)
			ICGV 00351	TMV Gn 13	
2009 rainy	PVS	107	1,185	868	37
2010 rainy	PC	103	2,227	1,717	30
2011 rainy	PC	150	2,302	1,837	25
2012 rainy	PC	221	1,343	894	50
2013 rainy	PC	150	1,853	1,576	18
Total / Mean		731	1,746	1,340	30

PVS = participatory variety selection; PC = paired comparisons

Table 19. Performance of ICGV 00351 and TVG 004 in on-farm trials in Thiruvannamalai district, Tamil Nadu, from 2008 to 2013 rainy seasons.

Season	Name of the trial	No. of trials	Mean pod yield (kg ha^{-1})			Superiority over TMV GN 13 (%)	
			ICGV 00351	TMV Gn 004	TMV Gn 13	ICGV 00351	TMV Gn 004
2008 rainy	PVS	99	1,429	1,270	996	43.5	28
2009 rainy	PVS	81	1,580	1,417	1,293	22.2	10
2010 rainy	PC	90	1,890	2,235	1,888	–	18
2011 rainy	PC	150	2,313	–	1,903	21.5	–
2012 rainy	PC	150	1,998	–	1,585	26.1	–
2013 rainy	PC	150	1,885	–	1,643	14.7	–
Total / Mean		720	1,901	1,636	1,587	20.0	3

PVS = participatory variety selection; PC = paired comparisons

1. Multi-location testing

Karnataka

UAS, Bangalore evaluated seven varieties across locations and seasons in Chitradurga, Tumkur, Chikballapur and Kolar districts for identification of superior varieties. In 2011 rainy season, CTMG 6 and CTMG 7 produced 65% to 83% greater pod yield over TMV 2 (pod yield of 1,647 kg ha^{-1}) while in 2013 rainy season, these two varieties produced 49% to 62% greater pod yield over TMV 2 (pod yield, 1,761 kg ha^{-1}). The international trials were also evaluated by the university for the two rainy seasons. In IMGVT, ICGV# 06046, 06049 and 06122 produced 22% to 26% greater pod yield over control Chintamani 2 (pod yield, 2.52 tons ha^{-1}) while ICGV# 07286 and 07403 in IDGVRT produced 19% to 43% greater pod yield over Chintamani 2 (pod yield, 2.15 tons ha^{-1}). In IFGRVT, ICGV# 06139, 06145 and 06146 produced 44% to 63% greater pod yield and had similar rust and LLS disease score as of Chintamani (pod yield, 2,109 kg ha^{-1}; disease score, 2).

UAS, Dharwad evaluated seven Spanish bunch varieties for pod yield and agronomic traits during 2012 rainy season. The pod yield ranged from 3.48 tons to 4.49 tons ha^{-1}, Dh 236 being the highest yielder and resistant to rust and LLS. It produced 16% greater pod yield over TMV 2 (pod yield of 3,479 kg ha^{-1}). The international trials were also evaluated by the university. ICGV# 07211, 07214, 00338 and 07213 in ISGVT produced 12 – 25% greater pod yield over JL 24 (2.86 tons ha^{-1}), ICGV 07211 and ICGVT 07213 being the resistant varieties to rust and LLS. The pod yield of ICGV 99160 in IMGVT was comparable to control, GPBD 4 (3,409 kg ha^{-1}); however, it showed greater 100-seed weight (51 g) than control (35 g). In ICGVT, ICGV 06189 produced 18% greater pod yield over TGLPS 3 (3.63 tons ha^{-1}). It showed 6% and 20% greater SMK% and 100 seed weight over TGLPS 3 (SMK, 88%; 100-seed weight, 54 g). Four varieties in IFDRGVT yielded at par and had similar disease score as of GPBD 4 (pod yield, 3.8 tons ha^{-1}; rust and LLS score, 2).

Odisha

OUAT, Bhubaneshwar identified ICGV 07220 as a drought tolerant variety and ICGV 10004 as an early maturing variety.

Tamil Nadu

TNAU identified ICGV# 01263, 96155 and 02266 as drought and foliar diseases resistant varieties and ICGV# 03128, 06146, 07018 and 07222 as high oil producing varieties.

All these varieties identified from multi-location or international trials will be further evaluated in state or national trials to identify promising varieties for release.

2. Generation of new breeding populations

During the period of 2007 – 2013, ICRISAT made a total of 919 crosses to generate breeding populations for early to medium duration, resistance to aflatoxin and foliar diseases, tolerance to drought and heat stress, confectionary and oil types, seed dormancy and minerals (Fe and Zn) dense types. In Karnataka, UAS Bangalore made 26 new crosses to generate breeding populations' specific to high yield, tolerance to drought, resistance to foliar diseases, early maturity and high shelling out-turn. The segregating generations (F_2 – F_7) involving 102 crosses were advanced and selections were made. UAS Dharwad selected 138 single plant selections for drought tolerance and 180 for early maturity and resistance to foliar diseases. In addition, 34 single plants and 23 bulks with confectionary characteristics were made. The marker-assisted backcross breeding has been initiated to select for rust resistance. BC_1F_2 generation was checked through MAS to pick up the segregants containing simple sequence repeats (SSRs) associated with rust resistance. UAS Raichur made 40 new crosses to generate foliar disease resistant breeding populations. In addition, 221 single plant selections and 12 bulks were advanced combining high yield, early maturity, resistance to pest and diseases, better pod or seed characteristics and high

oil types. Bihar Agricultural University, Sabour made 10 crosses, evaluated segregating populations ($F_2 – F_4$) and made promising selections. OUAT Bhubaneshwar made 10 crosses, evaluated segregating populations ($F_2 – F_7$) from 32 crosses and made promising selections.

3. Distribution of advanced lines and breeding populations

During 2007 – 2013, ICRISAT provided the partners with 192 sets of trials (short to medium duration, confectionary types, and resistant to aflatoxin, drought and foliar diseases). In addition, ICRISAT supplied 449 advanced lines and 236 trait-specific breeding populations for local adaptation and selection by the project partners.

B. Seed systems

The project was implemented in two phases, in partnership with Indian universities, such as Tamil Nadu Agricultural University, University of Agricultural Sciences – Dharwad (UAS – D), University of Agricultural Sciences – Bangalore (UAS-B), University of Agricultural Sciences – Raichur (UAS – R), Bihar Agricultural University, Orissa University of Agriculture and Technology – Bhubaneshwar and Bangladesh Agricultural Research Institute (BARI) – Bangladesh. Phase I was implemented in Karnataka and Tamil Nadu, India and phase II involved Odisha and Bihar, India and Bangladesh along with the phase I states. To foster growth and continuity, NGOs and farmer organizations were also included by the partner countries.

NARS ensured the availability and accessibility of breeders' and basic seeds to feed into both the formal and informal seed chains, which are considered to be important in groundnut production given the bulky nature of seed and low seed multiplication ratio. For these obvious reasons, formal seed chain of groundnut often falls short to meet the groundnut seed requirement in both these countries. Besides the capacity enhancement, infrastructure at SAUs was improved to undertake and handle seed production in large quantities. This has resulted in increased production of early generation seeds that were fed to seed chain. During 2008 – 2014, 8,124 tons of early generation seeds (NS, BS, FS) were produced by NARS partners, of which 8,088 tons was produced in India and 36.6 tons in Bangladesh. The groundnut farmers generally replenish the seeds after 3-4 crops, so saving own seed by farmers and farmer-to-farmer seed exchange is promoted to achieve enhanced adoption of new varieties.

Promoting adoption of new varieties through small seed packets has proven to be a successful model for groundnut production in India and Bangladesh. The small packs approach is increasingly gaining popularity as the most efficient and cost effective means of reaching more farmers with affordable quantities of seed and a wide range of preferred varieties. A total of 11,460 seed packets were distributed in four states in India during phases I and II, and 290 packets were distributed in Bangladesh during phase II. Reaching out to 11,500 farmers though small seed packets of new groundnut varieties is the most significant achievement towards adoption of new varieties.

Two alternate groundnut seed system models were developed and promoted in two states of India, ie, Karnataka and Tamil Nadu during phase I. The first model is the Panjabrao Deshmukh Krishi Vidyapeeth (PDKV) model that engages farmers in informal seed multiplication. Improved varieties in 2 kg packs are distributed to farmers who then multiply the seed over the two seasons, producing 20 kg in the first season and subsequently 200 kg in the second season. This generates enough seed to plant 1 ha area by the third season. In the third season, the farmers save 2 kg seeds from the selected plants and the cycle is repeated. This model enables the farmers to attain seed self-sufficiency sustaining high adoption rates among them.

The second seed system model, is semi-formal, and was implemented successfully in Karnataka state. In this model, the University supplies basic seed to farmers, who either offered land for certified seed production for the formal seed chain or Truthfully Labeled Seed (TLS), which was produced without

certification but monitored by the University, NGOs and farmer associations. A similar model was also used in Tamil Nadu. The semi-formal seed systems were found to be very successful in meeting local groundnut seed demand. In Tamil Nadu, the transport cost of 100 kg of pods alone is about ₹ 700, which is 20% of the cost of seed. Thus, the alternate seed systems reduced the costs of seed transportation by more than 10%.

The semi-formal model was implemented in the five districts including Erode and Thiiruvannamalai districts of Tamil Nadu and Bagalkot, Hiriyur and Raichur districts of Karnataka; and linkages were established between formal and informal seed sectors through supply of basic seed by the University. In Karnataka state, additional linkages were also facilitated through certification of seed production plots by the state seed certifying agencies. This seed was procured by state seed corporations or State Department of Agriculture. One hundred kg of basic seed of the variety ICGV 87846 was supplied to Agri-Business Incubation (ABI) Program of ICRISAT, Krishi Vignan Kendra – Sandhiyur and Regional Research Station – Vridhachalam for further multiplication and distribution of seeds to the farmers through this system. Similarly, 100 kg seed of ICGV 00351 was also supplied to ABI program of ICRISAT during 2010 rainy season. (Source: Tropical Legumes II project (2012) – Four Seasons of Learning and Engaging Smallholder Farmers: Progress of Phase I).

The support for both the formal and informal seed systems led to the increased production of certified and truthfully labeled (TL) seeds in the target sites. During 2008 – 2014, a total of 16,570 tons of CS and TL seeds were produced that accounted for 96 tons of its produce from Bangladesh in phase II. The quality seed of improved varieties can cover 138,000 ha of cropped area (@120 kg ha^{-1} seed rate used by farmers). The process of support to seed systems has also enhanced the collaboration between the TL II Project, NARS and farmer organizations.

C. Adoption and Impacts

Under TL II project, Raichur and Chitradurga districts in Karnataka and Erode and Thiruvannamalai districts in Tamil Nadu were chosen for introduction of new varieties and technologies. In each of these four districts, three villages were selected for intervention and were designated as “adopted” villages and three more villages were chosen as non-intervention villages and were designated as “control” villages. From each of the adopted villages, a sample of 30 farmers was chosen while this number was 15 in case of the control villages. Thus, in each of the two states, a sample of 180 farmers was drawn from the adopted villages while 90 farmers were chosen from the control villages. A baseline survey was conducted during 2007 – 2008, immediately after the cropping season to assess the socioeconomic status of the farmers, adoption and yield levels and benefit cost ratios of groundnut vis-à-vis other competing crops. The FPVS trials were conducted during the 2008 – 2009 rainy season in the so called adopted villages. Some new varieties were tested vis-à-vis the ruling varieties in the region to assess their comparative performance. The farmers were asked to rank the varieties based on the traits preferred by them. The varieties so selected by the farmers were taken up for seed multiplication. The farmers were supplied with small quantities of seed so that they will multiply the seeds and bulk the supply so that they can gradually switch over to the preferred varieties. In 2009 – 2010, an early adoption survey was commissioned to assess the dent created by the new varieties and prediction of any improvement in their yields and incomes due to such adoption.

Adoption of improved cultivars during baseline survey, 2007 – 2008

In Raichur, groundnut is grown in both rainy and post-rainy seasons, with more predominance in post-rainy season. Groundnut was grown only in the rainy season under rain-fed situations in case of Chitradurga district. The baseline sample villages in both the districts were completely dominated by single variety, ie, TMV-2 (nearly 90%) during the baseline survey of 2007 – 2008. The variety R 2001-2

that was released a few years ago failed to make any dent despite its high yield potential. This variety has undesirable pod characteristics that have led to its low market preference. Similarly, ICGV 91114 has not made any head way, despite some desired characteristics like short duration, tolerance to drought, moderate levels of resistance to rust and leafspots and good pod and kernel traits, mainly due to the lack of support from the seed production and distribution chain.

The baseline sample villages of Erode and Thiruvannamalai districts of Tamil Nadu are dominated by groundnut cultivation (>80%). In Erode district sample, CO-2 is the most popular variety in both the adopted and control villages. It occupied 52% of the groundnut area of the sample farms from the adopted villages. Its share was slightly lower at 48% in case of the sample farms of control villages. VRI-2 was the next most popular variety in Erode district, occupying 33% area in the adopted villages and 34% in the control villages. TMV-2 covered 9% area in the adopted villages and 13% in the control villages. In Thiruvannamalai district sample, POL-2 was the most preferred variety in the adopted villages, with a share of 55% in terms of total groundnut area. TMV-7 was also popular with a 44% share. The remainder of 1% area was under JL-24. The ranking order of varieties was similar in the control villages of the same district. POL-2 was the dominant variety in control villages with a share of 59% in the groundnut area of the sample farms. TMV-7 stood next with a 40% share. JL-24 had the remaining share of 1% area under it.

Adoption of improved cultivars during early adoption survey, 2009 – 2010

Karnataka

Just as in case of baseline survey year in Raichur district, the dominance of TMV-2 remained intact in the 2009 – 2010 period also. Nearly 95.4% groundnut area covered by TMV-2 and the remaining 4.6% covered by TL II introduced new varieties (R2001-02 and ICGV00350) during 2009 – 2010. This low adoption in Raichur might be due to inability of the farmers to access the information about new cultivars and developing a conviction about their superiority. Similarly, the stranglehold of TMV-2 was evident in Chitradurga district during early adoption surveys. Nearly 90.8% of total groundnut area in the sample villages was under TMV-2 and only 9.2% area was covered with project introduced varieties (ICGV 91114 and R2001-2).

Table 20 summarizes the cost of production of groundnut per quintal that has reduced from ₹ 2,145 to ₹ 1,983 between the baseline and early adoption surveys for the pooled sample. However, the unit cost reduction is much higher in case of Raichur sample (₹ 305) than Chitradurga sample (₹ 19). Overall, the productivity per ha has gone up nearly 29.7% which translated into unit cost reduction of 7.6% for the pooled sample.

Table 20. Unit cost reduction in groundnut cultivation, Karnataka sample.

Item	Raichur sample	Chitradurga sample	Pooled sample
Cost of production in baseline (2006 – 2007) ₹ per 100 kg	2,429	1,861	2,145
Cost of production in early adoption (2009 – 2010) ₹ per 100 kg	2,124	1,842	1,983
Reduction in cost of production (₹)	305	19	162
Percentage of reduction in unit cost of production (%)	12.6	1.0	7.6

Tamil Nadu

In Erode district, CO-2 occupied 48.1% of the cropped area in 2007 – 2008 and it was followed by VRI-2 (33.5%) and TMV-2 (10.4%). JL-24, TMV-7 and TMV-1 occupied minor areas. In 2009 – 2010, VRI-2 covered 62.5% area, followed by CO-2 (32.7%) and TMV-7 (1.9%). There was a token presence of new varieties in less than 1% area. In Thiruvannamalai district sample, POL-2 and TMV-7 were the farmer-

preferred varieties during the period of 2007 – 2008, occupying 56.6% and 42.3% areas, respectively. The remaining 1.1% area was under JL-24. In 2009 – 2010, the same varieties held sway over the groundnut farmers in the sample. POL-2 covered 64.5% area and TMV-7 had 21% share in the groundnut cultivated area. CO-2 accounted for 13.8% share. The new varieties had a token adoption in 0.7% area. Thus, new varieties failed to make a dent in the groundnut areas of the sample farmers, even though there was a churning between the old varieties. The cropped and groundnut areas decreased and the farmers seemed to shift to a more profitable crop in the absence of sustained efforts for popularizing the high yielding new varieties.

However, the new varieties offer a prospect for drastic reduction in unit cost of cultivation even in nominal terms because of their yield potential. In Erode district, cultivation of TVG0004 can bring down the unit cost of production by 39% as compared to CO-2. In case of ICGV00351 in Thiruvannamalai district, the reduction in unit cost of production would be more modest by 4.3% when compared to that of POL-2.

D. Capacity building

1. Human capital development

Bangladesh: Two breeders and one pathologist were trained on various aspects of breeding and diseases resistance screening. Four breeders participated in the training program on molecular breeding in Netherlands and Spain that was arranged by the Generation Challenge Program (GCP).

India: In phase I, one PhD student from TNAU Coimbatore and one MSc student from UAS Raichur completed their dissertations on groundnut research. Six researchers from Karnataka and Tamil Nadu received hands-on training on groundnut breeding and production technologies. Two scientists from TNAU Coimbatore were trained on use of marker-assisted breeding in groundnut at ICRISAT. **In phase II,** two students from Bihar have submitted their MSc thesis, one on heat tolerance in groundnut and another on root rot disease of groundnut, to BAU, Sabour. A scientist received hands-on training on breeding, screening for resistance to virus diseases, statistical modules, data management and integrated molecular breeding. From UAS Dharwad, a scientist and technician were trained on various aspects of integrated breeding (including molecular breeding) in groundnut. Four scientists from TNAU were trained on integrated molecular breeding and pre-breeding while a technician was trained on integrated legume crop management. Two students submitted their doctoral thesis on groundnut breeding. Researchers from India participated in the training program on molecular breeding in Netherlands and Spain that was arranged by GCP.

2. Infrastructure development

At TNAU, Coimbatore, the foliar disease screening facility was strengthened by installing a sprinkler system while at Tindivanam rain-out shelter were made for screening for drought tolerance and equipment for measuring drought tolerance traits were provided. Similar facilities were also established at UAS Raichur, Karnataka.

E. Lessons learned

- Feedback from the farmers helped the researchers in identification of farmer-preferred traits to breed new varieties;
- Participation of farmers in FPVS provided sense of belonging and ownership of the varieties by the farmers facilitating fast spread of new varieties;
- Capacity building and support to improve infrastructure development provided boost to adoption of new technology by the project partners;

- Distribution of seeds of promising varieties through ‘small seed packet’ has been a successful model for adoption of new groundnut varieties; however, our experience shows that for better adoption, seed packet should contain at least 10 – 20 kg seeds;
- Alternate seed systems adopted in the project have been very successful; however, these should be region specific considering local conditions of production, storage, seed laws and partners involved in the seed production and distribution chain;
- Increased collaboration seen between the TL II Project, NARS, civil society, farmer organizations, seed companies and traders;
- Adoption of improved varieties and integrated crop management technologies should go hand in hand for enhancing groundnut production and profitability; and
- A strong variety pipeline will be needed to replace the old and obsolete varieties with new varieties, matching the demand from farmers and the industry.